Australian Government

Office for Learning & Teaching

Enhancing engagement of agricultural students in learning mathematics through innovative teaching and learning strategies

Final report 2016

The University of Queensland
Project Leader: Dr Madan Gupta
Team Member: Professor Peter Adams

http://science.uq.edu.au/content/agmaths/

THE UNIVERSITY OF QUEENSLAND AUSTRALIA

Support for the production of this report has been provided by the Australian Government Office for Learning and Teaching. The views expressed in this report do not necessarily reflect the views of the Australian Government Office for Learning and Teaching.

2016

ISBN 978-1-76028-957-7 [PDF]
ISBN 978-1-76028-956-0 [PRINT]
ISBN 978-1-76028-958-4 [DOCX]

Acknowledgements

Support for this project was provided by the Australian Government Office for Learning and Teaching under Grant No. SD14-3592. The project team would like to acknowledge the contributions of Dr Guta Bedane, Mrs Christine Crossley and Ms Kirsten Ellis, who worked as Research Fellows at various stages of the project. Our special thanks to Mr Sami Derradji of Smart Sparrow, who helped us to develop the adaptive e-tutorials. Finally, we would like to thank all the students at UQ Gatton Campus who evaluated the adaptive e-tutorials and provided helpful feedback for further improvement.

List of acronyms

ALTC	Australian Learning and Teaching Council
ANAM	Australian Network of Adaptive Mathematics
AUDPC	Area under the disease progress curve
CQU	Central Queensland University
CSU	Charles Sturt University
OLT	Office for Learning and Teaching
UQ	The University of Queensland

Executive summary

Arguably the world is facing a perfect storm, with concurrent increases in population, rises in the expected standard of living, energy shortages and impacts of climate change. To feed the world in the coming years, agriculture must be modern, flexible, high-technology and resourced by smart, qualified people. Fundamental mathematical and quantitative skills are critical for agriculture students to succeed in their studies and careers. Many students study agriculture remotely, but learning mathematics in distance mode offers unique challenges because it is highly abstract, fundamentally sequential and based on visual-spatial symbolic notation. Traditional online teaching methods are often unsuccessful in engaging agriculture students in mathematics, so innovative approaches are required.

The aim of this seed project was to promote student engagement and learning of mathematics in agriculture disciplines through the development of adaptive e-tutorials using genuine, contextualised examples. The main focus was to support distance education students, but the resources and approaches developed are also of direct use to internal students.

Students of tertiary-level introductory mathematics courses consistently identify differential and integral calculus as the two most challenging topics to grasp, resulting in poor performance and a higher failure rate. This is especially problematic for agriculture students who often do not appreciate the usefulness of these topics, in part because of a lack of visible real-world examples in their chosen field of study.

This pilot study developed seven adaptive e-tutorials. Two e-tutorials relate to introductory concepts of differential and integral calculus (with 20 questions on each topic), and five relate to real-world case studies from various agricultural disciplines. Each case study introduces a real-world topic or problem, explains the basic mathematical concepts involved and provides a step-by-step method to solve the problem. These adaptive e-tutorials provide individualised guidance and instant feedback to students based on their level of understanding, 24 hours a day, without the necessity of lecturers or tutors being present with them. In addition to adaptive e-tutorials, a total of 40 videos were produced which give solutions of sample questions related to differential and integral calculus. The adaptive e-tutorials and videos can be assessed from the project website at <http://science.uq.edu.au/content/agmaths/>

The impact on student engagement and learning was assessed via a specific questionnaire developed to evaluate these adaptive e-tutorials. The positive comments by students – such as ‘I honestly found this the best learning tool of all’ and ‘I liked that the lesson was based on real applications, making it easy to engage with’ – sum up the many benefits offered by contextualised adaptive e-tutorials.

The outcomes of this pilot study have generated considerable interest from other higher education institutes in Australia. A future collaborative project with other Australian universities will assist in the development of an Australian Network of Adaptive Mathematics (ANAM).

Table of contents

Tables and figures

Tables

Figures

1. Background and aims

Australian universities engaged in agriculture education have generally introduced transitional mathematics courses for students who enter tertiary programs without completing Year 12 mathematics. At The University of Queensland's (UQ) Gatton Campus, Basic Mathematics (MATH1040) is offered to first-year Bachelor of Applied Science students enrolled in a number of disciplines – Agronomy, Horticulture, Animal Production, Equine Studies, Wildlife Science, Veterinary Technology, and Agribusiness. The course is offered in both internal and external modes. More than 1500 students have enrolled in this course during the past six years. On average, one-third of these students study mathematics in distance mode.

A number of successful teaching and learning technologies were incorporated in presentation of this course in internal mode which improved student engagement in lectures and reduced the failure rate (Gupta, 2009; 2010). In contrast, external students did not perform well, resulting in higher failure rates and significant dissatisfaction with the course. Data from our direct experience during the past six years, student feedback, and the literature (Smith & Ferguson, 2004; Chan & Waugh, 2007; Smith, Torres-Ayaia & Heindel, 2008) revealed that traditional online teaching methods are typically not effective at engaging these students in a mathematics course.

The authors have experimented with asynchronous and synchronous tools to promote engagement of distance education students in learning mathematics. Asynchronous tools such as the Blackboard Discussion Board and emails have been used in the past six years with limited success. Online synchronous tutorial sessions using Adobe Connect were also not well received by students. Only 15 per cent of students participated in the Discussion Board and only two per cent in online synchronous tutorials. The main reasons for low participation are that most external students work full-time with no fixed working schedule and also have family commitments, which greatly limit their ability to participate in online tutorials at set times.

Learning mathematics in distance mode offers unique challenges because it is abstract, sequential and has a large visual-spatial component with symbols and notations. Most distance education students are mature age students with diverse, typically weak, backgrounds in mathematics. Many of them also have 'maths phobia'. Anxiety, frustration, confusion and anger are common factors that contribute to disengagement with the mathematics course. In addition, agriculture students often do not appreciate the value of learning mathematics due to the lack of authentic, real-world examples in their chosen field of study. For all of these reasons, innovative approaches are needed to motivate and engage distance education students to learn mathematics.

The aim of this seed project was to promote student engagement and learning of mathematics in agriculture disciplines through the development of adaptive e-tutorials using genuine, contextualised examples. The main focus was to support distance education students, but the resources and approaches developed are also of direct use to internal students. The key intended outcomes were to:

1. identify and develop a set of genuine, real-world examples relevant to agricultural disciplines for two mathematics modules (differential and integral calculus)
2. develop adaptive e-tutorials for two mathematics modules using Smart Sparrow Adaptive eLearning Technology
3. develop solutions for sample examples in video format with screen and voice capture
4. disseminate the project findings via a workshop, university showcase days, conferences and journal publications.

2. Approach and methodology

Following Chickering and Gamson's (1999) seven principles of good practice in undergraduate education, the following three key innovations were implemented to promote student engagement and learning of mathematics in distance education mode:

1. Development of real-world examples
2. Development of adaptive e-tutorials
3. Development of videos

2.1 Development of real-world examples

Differential and integral calculus have been identified as the two most challenging topics in introductory, undergraduate mathematics courses typically taken by agriculture students, including in MATH1040 (Basic Mathematics) at The University of Queensland's Gatton Campus. Agriculture students do not appreciate its usefulness because of a lack of visible real-world examples in their chosen field of study. A review of some agricultural mathematics books (for example, Mitchell, 2004; Bill, 2009) reveals that they do not cover differential and integral calculus.

The first task in this project was to develop authentic, real world examples in a number of agricultural disciplines. This was achieved through consultation with agricultural scientists and by examining research in published literature. Five case studies were developed: three related to differential calculus and two related to integral calculus.

2.1.1 Case study 1: Optimum nitrogen rates (differential calculus)

Nitrogen (N) fertiliser is a major input for crop production. Nitrogen is typically applied to crops in chemical form (for example, the fertiliser urea), but can also be applied in organic forms, such as liquefied animal manure. The price of the nitrogen accounts for approximately one quarter of the total variable production cost for most agricultural crops. With the upward trend in fertiliser prices, farmers are always keen to apply optimal rates of N which maximise their profits. Determining optimal N application rates involves:

1. Collecting grain yield data at several N rates
2. Fitting a response function to the yield data
3. Determining the optimum N rate using differential calculus.

Real, authentic data published in the literature is used to demonstrate the application of differential calculus in determining optimum N rates. Students will learn how to determine:

- Agronomic optimum (that is, yield maximising) N rate
- Economic optimum (that is, profit maximising) N rate.

Further information about this case study is provided in Appendix B.

2.1.2 Case study 2: Optimum stocking rates (differential calculus)

The stocking rate (number of animals grazing per unit area) is one of the most important factors affecting animal productivity in areas such as liveweight gain, wool production and milk production. Over the years a number of studies have been conducted to correlate animal productivity with stocking rate. Generally, grazing experiments at several stocking rates are conducted to measure animal productivity per unit area. The relationship between animal productivity and stocking rate is usually curvilinear. Optimum stocking rate is defined as the rate at which animal productivity per hectare is maximum.

Real, authentic data published in the literature is used to demonstrate the application of differential calculus in determining optimum stocking rates. Students will learn how to determine:

1. Optimum stocking rate to achieve maximum liveweight gain per hectare
2. Liveweight gain per hectare at optimum stocking rate.

Further information about this case study is provided in Appendix B.

2.1.3 Case study 3: Optimum lysine requirements for pigs (differential calculus)

Pigs require a diet supplying energy, amino acids, minerals and vitamins. Amino acids are the building blocks for protein synthesis. These are crucial for growth, development and health of pigs. Lysine is one of the essential amino acids that cannot be synthesised by pigs and thus needs to be supplied via feedstuffs. Synthetic lysine is commonly used as an additive in pigs' rations to meet their dietary requirements. Many factors affect the level of lysine required for optimal growth of pigs. These factors include genotype, sex, liveweight and feed intake. Animal scientists often conduct feeding experiments to determine the response of pigs to various levels of lysine. The main objective is to find the optimum levels of lysine for maximum daily weight gain and minimum feed:gain ratio. Lysine requirement is generally expressed in grams per mega joules of digestible energy (g/MJ DE). By providing the optimum amount of dietary lysine to pigs, lean growth is maximised and feed costs are minimised.

Real, authentic data published in the literature is used to demonstrate the application of differential calculus in determining optimum lysine levels to achieve the maximum performance of pigs. Students will learn how to determine:

1. Optimum lysine level for maximum daily weight gain
2. Optimum lysine level for minimum feed:gain ratio.

Further information about this case study is provided in Appendix B.

2.1.4 Case study 4: Bioavailability of drugs (integral calculus)

Drugs can be administered to human and animal patients through a number of routes such as intravenously, orally, rectally and nasally. The proportion of the dose that enters into systemic blood circulation in a patient depends upon the route used to administer the drug. This is called the bioavailability of the drug, and can significantly affect the desired outcome arising from taking the drug.

Drugs administered intravenously have 100 per cent bioavailability. However, when a drug is administered through a non-intravenous route (for example, orally), its bioavailability is generally less than 100 per cent because of incomplete absorption and other factors such as first-pass metabolism of the drug by the body.

Bioavailability of a drug for a non-intravenous route is determined experimentally by administering the drug to a number of healthy subjects (human volunteers or animals) by the selected route and also intravenously. Blood samples from each subject are collected at regular intervals to determine the drug concentration levels in the blood plasma. Drug concentration curves are then plotted to determine the area under the curve for each route.

Real, authentic data published in the literature will be used to demonstrate the application of integral calculus in determining bioavailability of drugs. Students will learn how to determine:

1. The area under the curve for intravenous route
2. The area under the curve for non-intravenous route.

Further information about this case study is provided in Appendix B.

2.1.5 Case study 5: Assessment of plant disease severity (integral calculus)

Plant disease severity during the growing season depends on several factors, including crop variety and date of planting. Plant scientists often conduct field experiments to develop disease progress curves by monitoring plant disease severity a number of times during the growing season. The main objective is to find the area under the disease progress curve (AUDPC), which provides a useful overall measure to compare plant disease severity for various crop varieties planted at different planting dates. The AUDPC indicates the cumulative amount of disease over the season. Larger areas under the curve represent a more severe disease occurrence than smaller areas. This information can then be used to compare the plant disease susceptibility of various crop varieties. It can also be used to identify the optimum planting date for a given crop variety, which enables slow disease progress.

Real, authentic data published in the literature will be used to demonstrate the application of integral calculus in assessing plant disease severity. Students will learn how to determine:

1. The area under a disease progress curve for early planting.
2. The area under a disease progress curve for late planting.

Further information about this case study is provided in Appendix B.

2.2 Development of adaptive e-tutorials

The second task in this project was to develop adaptive e-tutorials for two mathematics modules: differential calculus and integral calculus. These adaptive e-tutorials were developed using Smart Sparrow Adaptive eLearning Technology <https://www.smartsparrow.com/adaptive-elearning/>. This technology was found to be highly successful in developing adaptive tutorials for engineering mechanics courses in an earlier ALTC-funded project (Prusty & Russell, 2011). Adaptive e-tutorials provide individualised guidance and instant feedback to students based on their levels of understanding, 24-hours a day, without the necessity of lecturers or tutors being present with them.

A total of seven adaptive e-tutorials were developed, two related to introductory concepts of differential and integral calculus, and five related to the above case studies. Adaptive tutorials for the introductory concepts are comprised of 40 questions – 20 each for differential and integral calculus. However, every time a question is presented to a student, the variables in questions are assigned randomly. Feedback is provided specific to the question presented to the student. The adaptive tutorial for each case study introduces the real-world topic or problem, provides the basic mathematical concepts involved, and finally gives the step-by-step method required to solve the problem. These adaptive e-tutorials can be assessed using the following links:

- Basics of differential calculus https://aelp.smartsparrow.com/learn/open/i813jw1h
- Basics of integral calculus https://aelp.smartsparrow.com/learn/open/iiwvaduv
- Optimum nitrogen rates https://aelp.smartsparrow.com/learn/open/hz1c1lml
- Optimum stocking rates https://aelp.smartsparrow.com/learn/open/4n5gyeby
- Optimum lysine requirements for pigs https://aelp.smartsparrow.com/learn/open/z1shf4g5
- Bioavailability of drugs https://aelp.smartsparrow.com/learn/open/2zzbu5zb
- Assessment of plant disease severity https://aelp.smartsparrow.com/learn/open/8vckv3jr

2.3 Development of videos

The third task in this project was to develop videos for solutions of sample questions related to differential and integral calculus. A total of 40 videos were produced using Tablet PC and Camtasia Studio. These include complete dynamic modelling of solutions by producing video clips with screen and voice capture. These videos are particularly useful for distance education students who can learn the step-by-step procedure of solving questions by observing visually and hearing the teacher's voice. In essence, these videos simulate the face-to-face method used to clarify and explain a solution to a problem to internal students in tutorial classes. Students can watch the videos at their own pace and in their own time. These videos can be assessed from the project website at <http://science.uq.edu.au/content/agmaths/>

2.4 Implementation of the resources developed

Two of the case studies (Optimum nitrogen rates and Bioavailability of drugs) were deployed in Semester 1, 2015 for MATH1040 (Basic Mathematics) at The University of Queensland's Gatton Campus. These case studies were introduced in the lectures and students were asked to read the following two research papers so that they had some background to the real-world problems covered in these case studies:

Kwaw-Mensah, D. and Al-Kaisi, M. (2006). Tillage and nitrogen source and rate effects on corn response in corn-soybean rotation. *Agronomy Journal,* 98:507-513.

LeTraon, G., Burgaud, S. and Horspool, L.J.I. (2008). Pharmacokinetics of cimetidine in dogs after oral administration of cimetidine tablets. *Journal of Veterinary Pharmacology Therapeutics*, 32:213-218.

The above case studies were made available to students through the Blackboard site of MATH1040 course using the **Web Link** functionality in the **Content Area** of the Blackboard. The Web Link allowed the integration of the course Blackboard site with the external web-based Learning Tool "Adaptive eLearning Platform of Smart Sparrow" where all the cases studies are hosted.

Students of MATH1040 course accessed these case studies in a similar way as they accessed weekly quizzes. While weekly quizzes were compulsory and counted towards summative assessment, these two case studies were optional. In order to get reasonable response of student evaluation of these case studies, a maximum of two bonus marks were assigned for each case study. Students were able to secure part marks depending upon how many steps they were able to perform correctly first-time and how many in subsequent attempts after receiving adaptive feedback at each stage of the case study. This was one of the key features of adaptive tutorials which promoted student engagement as they were able to get continuous help automatically without the necessity of lecturers or tutors sitting beside them. A total of 124 out of 241 students enrolled in the course completed these case studies. After completion of these case studies, students were asked to complete a survey developed by Smart Sparrow (https://www.smartsparrow.com). All those students who completed the case studies also had to participate in this survey as it was mandatory for them to register their bonus marks in the Grade Centre of the course Blackboard site. Survey questions and student responses are summarised in Section 4.

3. Outputs and findings

All the proposed outcomes of this seed project were achieved (Table 1). In consultation with the OLT, the approach to disseminate the outcomes of the project was modified. The original plan was to invite academic staff from other universities teaching mathematics to agriculture students for a one-day workshop at UQ to demonstrate the outcomes of the project. Given the budget constraints in the higher education sector, many prospective collaborators may not have been able to attend this workshop. Thus, the alternative approach was followed wherein the prospective collaborators for the next phase of the project were contacted first via email and then the outcomes of the project were presented to them either via Skype or by visiting their institutes.

Table 1: Proposed and actual project outcomes and deliverables.

Proposed Outcome	**Actual Outcome**
Identify and develop a set of genuine, real-world examples relevant to agricultural disciplines for two mathematics modules (differential and integral calculus)	Achieved. Five real-world case studies were developed to demonstrate the application of differential and integral calculus in various agriculture disciplines.
Develop adaptive e-tutorials for two mathematics modules using Smart Sparrow Adaptive eLearning Technology	Exceeded. A total of seven adaptive e-tutorials were developed using smart Sparrow Adaptive eLearning Technology.
Develop solutions for sample examples in video format with screen and voice capture	Achieved. Forty videos were produced to demonstrate the solutions of basic questions related to differential and integral calculus.
Disseminate research findings via a workshop, university showcase days, conferences and journal publications	Achieved. Detailed discussions were held with the following academics who have shown keen interest in collaboration for the future project: • Dr Azizur Rahman and Dr Michael Kemp, School of Computing and Mathematics, Charles Sturt University (CSU), Wagga Wagga, NSW • Dr Nadine Adams, Learning and Teaching Services, Division of Higher Education, Central Queensland University (CQU), Mackay Ooralea Campus, Queensland. A paper was presented at the International Congress on Mathematical Education. The authors are in the process of writing a paper for publication in a peer-reviewed journal.

Outside of the scope of the seed grant, a website <http://science.uq.edu.au/content/agmaths/> has been developed to provide all available resources related to the project. This website will be useful in further dissemination of the project outcomes to the higher education sector in Australia and overseas.

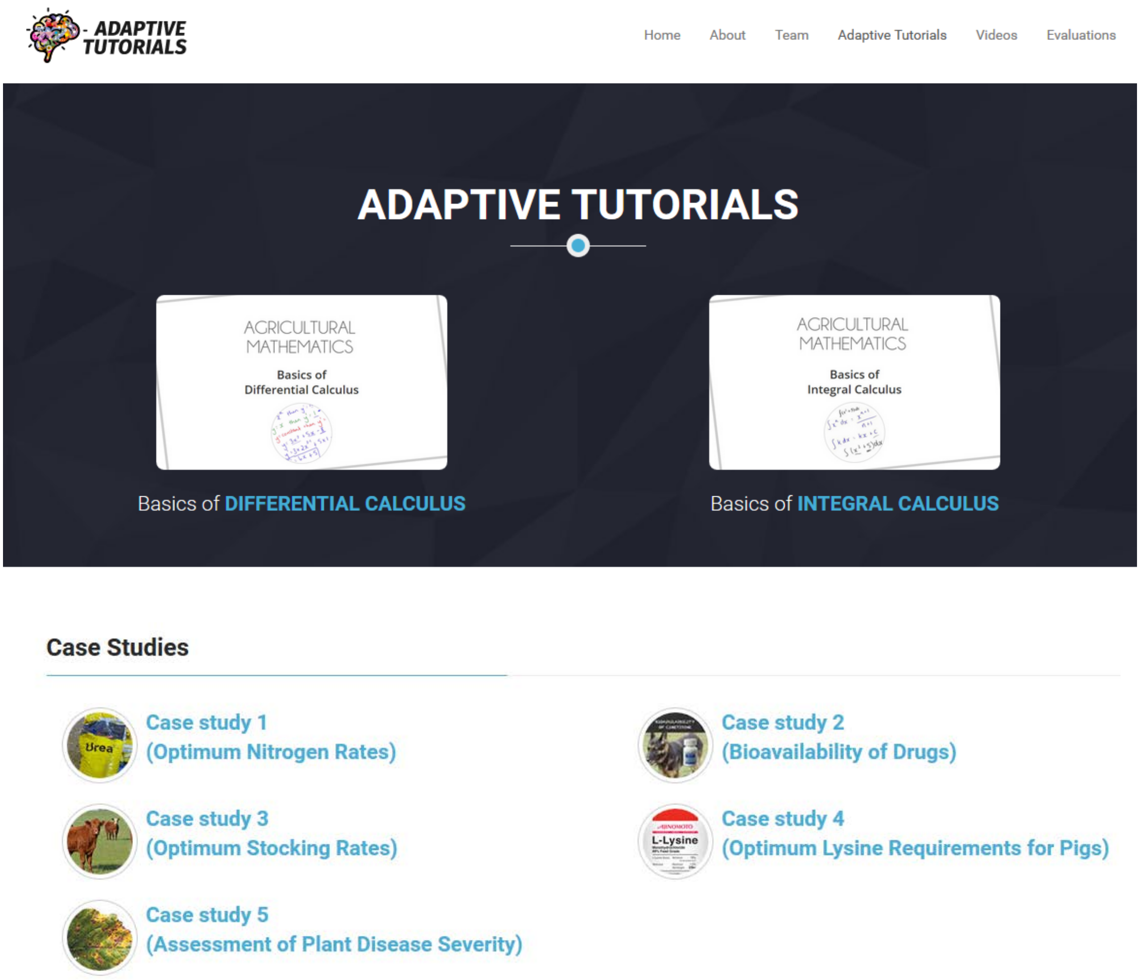

Figure 1: Agricultural mathematics website home page.

Factors impacting on the project

The project involved the use of new and innovative Adaptive eLearning Technology in development of adaptive e-tutorials based on real-world case studies. There were many unknown factors in the adoption of this technology. A number of factors impacted the project (Table 2). Some were critical to the successful outcomes of the project while others impeded the project resulting in delayed timeline. However, all the stated objectives were achieved in the end.

Table 2: Success and impeding factors in the project

Success factors	**Impeding factors**
• Motivation and enthusiasm of project team • Skill and experience of project team • Well defined project methodology • Regular team meetings • Helpful feedback from students • Critical review of case studies by academic tutors • Willingness of agricultural scientists to share their knowledge and resources • Good management of project work • Willingness and help of IT experts in development of high quality project website • Dissemination of project outcomes at international conference	• Delay in implementation of Smart Sparrow Technology within the UQ Learning Management System • High academic workloads • Steep learning curve in development of adaptive e-tutorials • Underestimation of the time needed in development and debugging of adaptive e-tutorials

Applicability to other institutions/locations

This project has made significant contributions in developing real-world case studies related to differential and integral calculus. These case studies were deployed and tested in a first-year course at UQ. The project website gives full information about all the resources developed which are of direct use to many Australian Universities offering similar transitional mathematics courses. Differential and integral calculus are also globally studied by upper-secondary level students. These resources can also be effectively used in secondary schools in Australia or internationally.

The project outcomes were presented at the 13th International Congress on Mathematical Education, Hamburg, Germany, 24-31 July 2016. Many delegates at this conference showed keen interest in adapting these resources at their institutes.

4. Impact, dissemination and evaluation

4.1 Impact on student engagement and learning

Two of the case studies (Optimum nitrogen rates and Bioavailability of drugs) were deployed in Semester 1, 2015 for MATH1040 (Basic Mathematics) at The University of Queensland's, Gatton Campus. Feedback from the students was positive, as shown in the following graphs summarising student survey results.

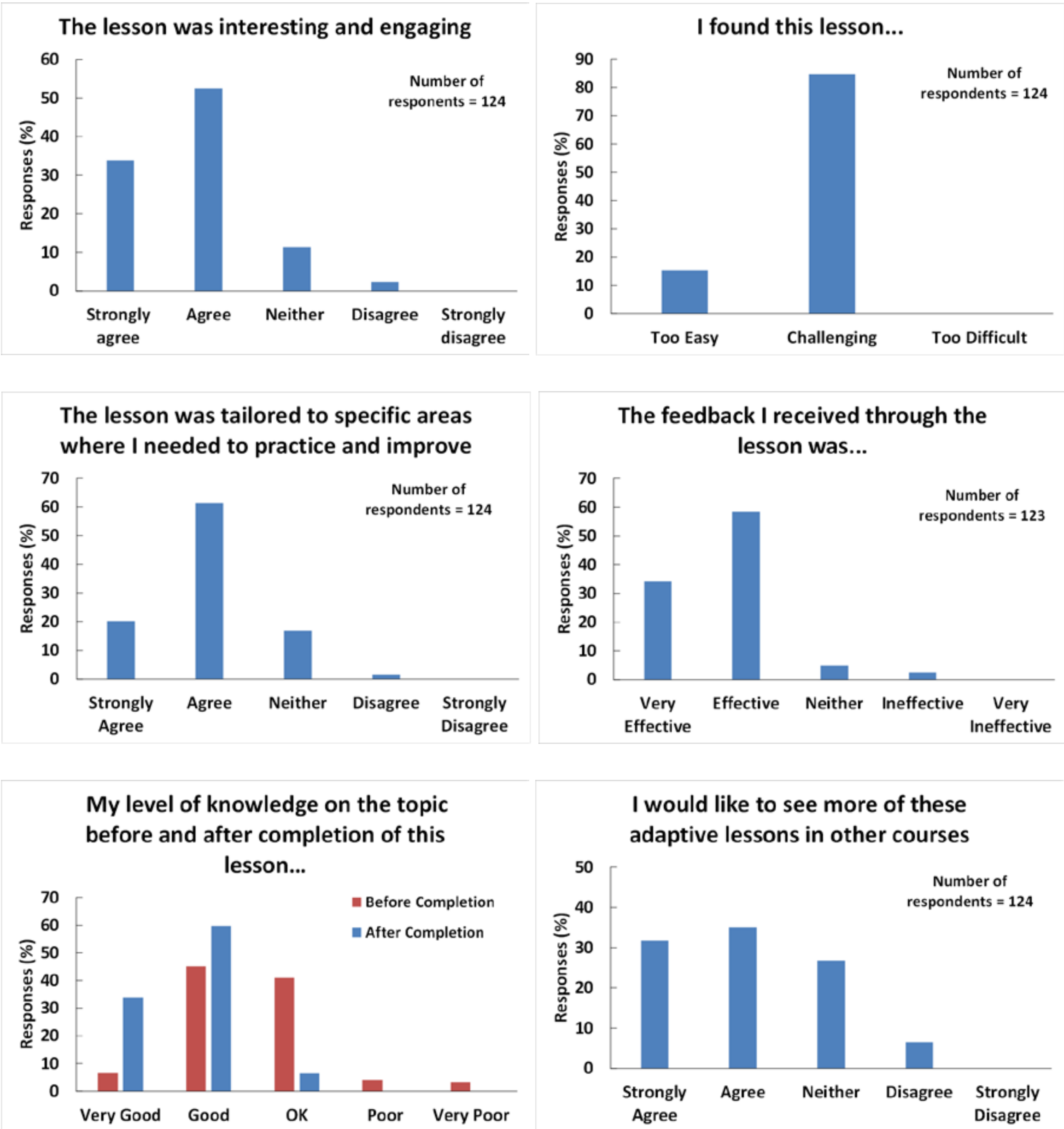

Figure 2: Student feedback on adaptive e-tutorials.

The following comments from students in the open-ended questions further demonstrate the benefits of developing real-world case studies:

- *[I] honestly found this the best learning tool of all. Being an external student that also has to juggle full time work I found this the most engaging and also found I retained the information a lot faster.*
- *The mathematics was linked to a real life situation, which enabled me to understand why you would use the mathematic equations.*
- *Interactive, fresh way to teach applying differentiation in real life situations.*
- *I now have a better understanding of maximisation procedure.*
- *I liked that the lesson was based on real applications, making it easy to engage with.*
- *You should have designed these for every topic in this course. I learnt A LOT from that short segment more than I could have from a lecture or anything else that is so antiquated for this day and age of external online teaching.*

Clearly, the students would like to have adaptive e-tutorials for all the topics covered in the course. This would further promote their learning in mathematics.

4.2 Teaching and learning grant

Based on the success of this seed project, the project team secured further funding of $200,000 from the Deputy Vice-Chancellor (Academic) of The University of Queensland for a project entitled ‘Technology-enhanced learning strategies for real-world mathematics’. Under this project, 20 real-world case studies will be developed to demonstrate the application of mathematics in a wide range of disciplines, including agriculture, business, sciences, health sciences, veterinary sciences, social sciences and engineering. These case studies will be implemented for 4000 students in six large first-year courses at UQ Gatton and St Lucia campuses. Smart Sparrow Adaptive eLearning Technology will be used to develop e-tutorials based on these case studies to provide engaging and challenging interactive learning experiences.

4.3 Dissemination

The outcomes of this project have been or will be shared using the following methods:

- Discussion with Dr Azizur Rahman and Dr Michael Kemp, School of Computing and Mathematics, CSU, Wagga Wagga, NSW.
- Discussion with Dr Nadine Adams, Learning and Teaching Services, Division of Higher Education, CQU, Mackay Ooralea Campus, Queensland.
- Gupta, M. and Adams, P. (2016). Adaptive Tutorials: An E-learning Approach Fostering Student Engagement in Mathematics. Paper presented at the 13th International Congress on Mathematical Education, Hamburg, Germany, 24-31 July 2016 (Appendix C).

- The authors intend to submit a paper for publication in The International Journal of Science, Mathematics and Technology Learning.
- A website <http://science.uq.edu.au/content/agmaths/ > has been developed to further disseminate the outcomes of this seed project.

4.4 Evaluation

The progress of the project was regularly monitored by holding regular meetings with project team members. For example, each case study was reviewed by the Project Leader and team members. Feedback from each team member was incorporated and improved version of the case study was then released for deployment to students through the Learning Management System at The University of Queensland.

A teleconference was also held on 23 April 2015 between the project team and Ms Tracey Bruce, Senior Administration Officer, Office for Learning and Teaching, to discuss the interim progress report. During this teleconference, detailed discussions were held about the progress made thus far and the need for an extension to successfully complete the project's objectives.

No independent evaluation was required for this seed project. However, the feedback from other higher education institutes was encouraging.

National Impact

Case studies were reviewed by Prof. Josua Pienaar, Deputy Dean (Learning and Teaching) School of Engineering and Technology, Central Queensland University (Appendix D). His assessment is given below:

"Thank you for the opportunity to review the case studies that you have created to teach differential and integral calculus with relation to the field of agriculture. These case studies provided students with authentic assessments in which to master and apply differential and integral calculus. I found the feedback given and the ability to reattempt very beneficial. Case studies of a similar nature to those that you have provided for your agriculture students would be most beneficial for our engineering and built environment students."

International Impact

Under the UQ Global Engagement program, the Project Leader has been invited by Professor Stefan Ufer, Department of Mathematics, Ludwig-Maximilians-Universität (LMU), Munich, Germany, to present a course ***"Adaptive and authentic approaches to learning mathematics"***. Full details of the course are given below:

Course Description:

This course is designed for students to learn new and innovative ways of teaching mathematics. Using calculus (school-level) as an example, participants will learn how to engage and motivate 21st century students in learning mathematics through the use of authentic, real-world case studies. They will also learn the many pedagogical benefits of using Adaptive Tutorials in their future teaching career in Mathematics. The course will be based on existing online case scenarios developed by the course leader. Participants will have the opportunity to analyse these scenarios from a mathematics education perspective and adapt parts of them to a German context during the course.

Goals of the Course:

1. To investigate innovative pedagogical and technological strategies (eg. adaptive tutorials, real-world case studies) for teaching mathematics.
2. To learn how to develop adaptive tutorials and real-world case studies for teaching mathematics.

References

Bill, R. (2009). *Medical Mathematics and Dosage Calculations for Veterinary Processionals*. Wiley-Blackwell, USA.

Chan, M.S. and Waugh, R.F. (2007). Factors Affecting Student Participation in the Online Learning Environment at the Open University of Hong Kong. *Journal of Distance Education,* 21(3):23-38.

Chickering, A.W. and Gamson, Z.F. (1999). Development and Adaptations of the Seven Principles for Good Practice in Undergraduate Education. *New Directions for Teaching and Learning,* 1999(80):75-81.

Gupta, M.L. (2009). Using Emerging Technologies to Promote Student Engagement and Learning in Agricultural Mathematics. *The International Journal of Learning*, 16(10): 497-508.

Gupta, M.L. (2010). Interactive Teaching and Learning by Using Student Response Systems. *The International Journal of Learning,* 17 (5): 371-384.

Jones, R.J. and Sandland, R.L. (1974). The relation between animal gain and stocking rate – Derivation of the relation from the results of grazing trials. *Journal of Agricultural Science,* 83:335-342.

Kwaw-Mensah, D. and Al-Kaisi, M. (2006). Tillage and nitrogen source and rate effects on corn response in corn-soybean rotation. *Agronomy Journal,* 98:507-513.

LeTraon, G., Burgaud, S. and Horspool, L.J.I. (2008). Pharmacokinetics of cimetidine in dogs after oral administration of cimetidine tablets. *Journal of Veterinary Pharmacology Therapeutics*, 32:213-218.

Meena, P.D., Chattopadhyay, C., Meena, S.S. and Kumar, A. (2011). Area under disease progress curve and apparent infection rate of Alternaria blight disease of Indian mustard (*Brassica juncea*) at different plant age. *Archives of Phytopathology and Plant Protection*, 44(7):684-693.

Mitchell, N.H. (2004). Mathematical Applications in Agriculture. Delmar Learning, USA.

Moore, K.L., Mullan, B.P, Campbell, R.G. and Kim, J.C. (2013). The response of entire male and female pigs from 20 to 100-kg liveweight to dietary available lysine. *Animal Production Science,* 53:67-74.

Prusty, B.G. and Russell C. (2011). Engaging students in learning threshold concepts in engineering mechanics: adaptive eLearning tutorials. *17th International Conference on Engineering Education*, Belfast, Northern Ireland, 2011.

Smith, G.G. and Ferguson, D. (2004). Diagrams and math notation in e-learning: growing pains of a new generation. *International Journal of Mathematical Education in Science and Technology,* 35(5):681-695.

Smith, G.G., Torres-Ayaia, A.T. and Heindel, A.J. (2008). Disciplinary Differences in E-learning Instructional Design: The Case of Mathematics. *Journal of Distance Education,* 22(3):63-88.

Appendix A: Certification by Deputy Vice-Chancellor

Certification by Deputy Vice-Chancellor (or equivalent)

I certify that all parts of the final report for this OLT grant provide an accurate representation of the implementation, impact and findings of the project, and that the report is of publishable quality.

Name: Professor Joanne Wright Date: 24 / 01 / 2016

Appendix B: Case studies

Case Study 1: Optimum nitrogen rates

Kwaw-Mensah, D. and Al-Kaisi, M. (2006). Tillage and nitrogen source and rate effects on corn response in corn-soybean rotation. *Agronomy Journal,* 98:507-513.

This three-year study was conducted to evaluate corn response to three tillage systems (no-tillage, strip-tillage, and chisel plough) and four N application rates (0, 85, 170 and 250 kg N/ha) across two sources of N, commercial fertiliser and liquid swine manure, in a corn-soybean rotation. Corn grain yield response to different tillage systems was found to not be significantly different across N rates for both N sources. Thus, the authors used grain yield data averaged across three years and across all tillage systems to develop the following quadratic functions giving relationships between corn grain yield and N application rate:

$$y = 7780 + 31.9x - 0.085x^2 \qquad \text{(commercial fertilser)}$$

$$y = 7280 + 35.5x - 0.085x^2 \qquad \text{(liquid swine manure)}$$

where: $y = \text{Corn grain yield (kg/ha)}$

$x = \text{N rate (kg/ha)}$

Example – Commercial fertiliser

Using the yield response function for commercial fertiliser, determine (a) Agronomic optimum (yield maximising) N rate, and (b) Economic optimum (profit maximising) N rate. Assume that the price of corn is \$0.3/kg and that the price of N in commercial fertiliser is \$0.8/kg.

(a) Agronomic optimum (yield maximising) N rate

Here, the aim is to find out the N rate which will maximise the crop yield. We will make use of differential calculus to determine the agronomic optimum N rate.

Step 1: Let us call the yield response function for commercial fertliser as Eqn (1)

$$y = 7780 + 31.9x - 0.085x^2 \qquad \text{Eqn (1)}$$

Step 2: Find the first derivative of Eqn (1)

We will make use of the following rules:

If $y = x^n$, then $y' = nx^{n-1}$
If $y = x$, then $y' = 1$
If $y = \text{constant}$, then $y' = 0$

$$y = 7780 + 31.9x - 0.085x^2$$
$$y' = 0 + 31.9 \times 1 - 0.085(2x^{2-1})$$
$$y' = 31.9 - 0.17x$$

Step 3: Set $y' = 0$ and find the value of x

$$y' = 0$$
$$31.9 - 0.17x = 0$$
$$x = \frac{31.9}{0.17} = 188$$

Step 4: Find the second derivative of Eqn (1)

The second derivative can be found by differentiating the first derivative (y').

$$y' = 31.9 - 0.17x$$

We will make use of the following rules to solve this question:

If $y = x$, then $y' = 1$
If $y = \text{constant}$, then $y' = 0$

$$y' = 31.9 - 0.17x$$
$$y'' = 0 - 0.17 \times 1 = -0.17$$

Step 5: Perform the second derivative test.
As y'' is negative, the value of $x = 188$ will give us the maximum value of y.

Step 6: Find the maximum value of y by substituting $x = 188$ in Eqn (1).

$$y = 7780 + 31.9 \times 188 - 0.085 \times (188)^2$$
$$y = 10773 \text{ kg/ha}$$

Answer: We can achieve maximum corn yield of 10773 kg/ha by applying nitrogen at the rate of 188 kg/ha.

(b) Economic optimum (profit maximising) N rate

Here, the aim is to find out the N rate which will maximise the profit. This will depend on the prevailing prices of corn and N fertiliser. Before we make use of differential calculus to determine the economic optimum N rate, we need to develop a relationship between profit and N rate.

Profit ($/ha)= Price of corn ($/kg) $\times$ Corn yield (kg/ha) - Price of N fertilser ($/kg) $\times$ N rate (kg/ha)

Using the price of corn = $0.3/kg, price of commercial N fertiliser = $0.8/kg, and the corn yield response function for commercial fertiliser, we can rewrite the above profit equation as follows:

$$\begin{aligned}\text{Profit}\,(P) &= 0.3(7780+31.9x-0.085x^2)-0.8x\\ &= 2334+9.57x-0.0255x^2-0.8x\\ &= 2334+8.77x-0.0255x^2\end{aligned}$$

Step 1: Let us call the above profit function as Eqn (2)

$$P = 2334+8.77x-0.0255x^2 \qquad \text{Eqn (2)}$$

Step 2: Find the first derivative of Eqn (2)

We will make use of the following rules to solve this question:

If $y = x^n$, then $y' = nx^{n-1}$
If $y = x$, then $y' = 1$
If $y = \text{constant}$, then $y' = 0$

$$\begin{aligned}P &= 2334+8.77x-0.0255x^2\\ P' &= 0+8.77\times 1-0.0255(2x^{2-1})\\ P' &= 8.77-0.051x\end{aligned}$$

Step 3: Set $P' = 0$ and find the value of x

$$\begin{aligned}P' &= 0\\ 8.77-0.051x &= 0\\ x &= \frac{8.77}{0.051} = 172\end{aligned}$$

Step 4: Find the second derivative of Eqn (2)

The second derivative can be found by differentiating the first derivative (y').

$$P' = 8.77 - 0.051x$$

We will make use of the following rules to solve this question:

If $y = x$, then $y' = 1$
If $y = \text{constant}$, then $y' = 0$

$$P' = 8.77 - 0.051x$$
$$P'' = 0 - 0.051 \times 1 = -0.051$$

Step 5: Perform the second derivative test
As P'' is negative, the value of $x = 172$ will give us the maximum value of P.

Step 6: Find the maximum value of P by substituting $x = 172$ in Eqn (2).

$$P = 2334 + 8.77 \times 172 - 0.0255 \times (172)^2$$
$$P = \$3088/\text{ha}$$

Step 7: Find the economic yield by substituting $x = 172$ in Eqn (1).

$$y = 7780 + 31.9 \times 172 - 0.085 \times (172)^2$$
$$y = 10752 \text{ kg/ha}$$

Answer: We can achieve maximum profit of $3088/ha by applying nitrogen at the rate of 172 kg/ha. Economic yield at this N rate is 10752 kg/ha.

Note that the above profit of $3088/ha is not the net profit, but instead is the profit after allowing only for the cost of fertiliser. There are many other costs (for example, land, machinery, chemicals and labour) associated with crop production which need to be taken into account before arriving at the net profit value. Figure 3 shows the yield response function and also depicts that the economic yield is less than the agronomic yield.

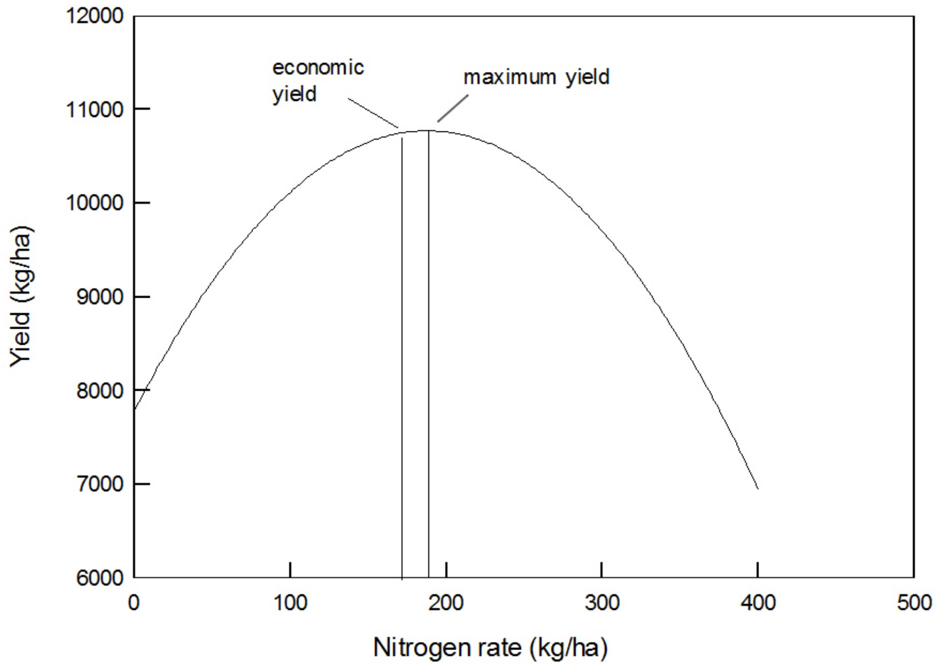

Figure 3: Agronomic yield and economic yield for commercial fertiliser N rate for corn.

Case Study 2: Optimum stocking rates

Jones, R.J. and Sandland, R.L. (1974). The relation between animal gain and stocking rate – Derivation of the relation from the results of grazing trials. *Journal of Agricultural Science,* 83:335-342.

This study presents the results from an experiment where beef cattle at a number of stocking rates were grazed continuously on three tropical pastures: (i) Setaria plus Desmodium, (ii) Setaria plus Siratro, and (iii) Setaria plus 336 kg N/ha/year. The first two pastures are mixtures of grass and legume whereas the third pasture is nitrogen fertilised grass. The experiment was conducted at the CSIRO Pasture Research Station, Samford, near Brisbane from 1969 to 1972. Stocking rates were 1.11, 1.73, 2.35, and 2.96 animals/ha on the grass-legume pastures and 2.96, 3.58, 4.20, 4.82 and 5.44 animals/ha on the nitrogen fertilised pasture. Based on data collected over three years, the authors developed the following relationships between annual liveweight gain and stocking rate:

$$y = 241x - 56.8x^2 \qquad \text{(Pasture 1: Setaria – Desmodium pasture)}$$
$$y = 212x - 43.7x^2 \qquad \text{(Pasture 2: Setaria – Siratro pasture)}$$
$$y = 176x - 15.8x^2 \qquad \text{(Pasture 3: Setaria plus 336 kg N/ha/annum)}$$

where: $y = \text{Liveweight gain (kg/ha/year)}$
$x = \text{Stocking rate (animals/ha)}$

Example - Pasture 1

Using the animal response function for Pasture 1, determine (a) optimum stocking rate, and (b) maximum liveweight gain.

(a) Optimum stocking rate

Here, the aim is to find out the socking rate which will maximise the liveweight gain. We will make use of differential calculus to determine the optimum stocking rate.

Step 1: Let us call the animal response function for Pasture 1 as Eqn(1)

$$y = 212x - 43.7x^2 \qquad \text{Eqn (1)}$$

Step 2: Find the first derivative of Eqn (1)

We will make use of the following rules to solve this question:

If $y = x^n$, then $y' = nx^{n-1}$
If $y = x$, then $y' = 1$

$$y = 241x - 56.8x^2$$
$$y' = 241 \times 1 - 56.8(2x^{2-1})$$
$$y' = 241 - 113.6x$$

Step 3: Set $y' =$ 0 and find the value of x

$$y' = 0$$
$$212 - 87.4x = 0$$
$$x = \frac{212}{87.4} = 2.4$$

Step 4: Find the second derivative of Eqn (1)

The second derivative can be found by differentiating the first derivative (y').

$$y' = 241 - 113.6x$$

We will make use of the following rules to solve this question:

If $y = x$, then $y' = 1$
If $y = \text{constant}$, then $y' = 0$

$$y' = 241 - 113.6x$$
$$y'' = 0 - 113.6 \times 1 = -113.6$$

Step 5: Perform the second derivative test.

As y'' is negative, the value of $x = 2.4$ will give us the maximum value of y.

(b) Maximum liveweight gain

Find the maximum value of y by substituting $x = 2.4$ in Eqn (1).

$$y = 212 \times 2.4 - 43.7 \times (2.4)^2$$
$$y = 257 \text{ kg/ha}$$

Answer: We can achieve maximum liveweight gain of 257 kg/ha by using stocking rate of 2.4 animals/ha.

Case Study – 3 (Optimum lysine requirements for pigs)

Moore, K.L., Mullan, B.P, Campbell, R.G. and Kim, J.C. (2013). The response of entire male and female pigs from 20 to 100-kg liveweight to dietary available lysine. *Animal Production Science,* 53:67-74.

This study presents the results from two experiments conducted at the Department of Agriculture and Food Western Australia's Medina Research Centre. In Experiment 1, a total of 350 male and female pigs were used with five levels of lysine (0.6, 0.7, 0.8, 0.9 and 1.0 g/MJ DE). Pigs were an average of 22.3 kg liveweight at the start of the experiment and the experimental diets were fed until they reached 53.1 kg liveweight. In Experiment 2, a total of 420 male and female pigs were used with five levels of lysine (0.4, 0.5, 0.6, 0.7 and 0.8 g/MJ DE). Pigs were an average of 49.6 kg liveweight at the start of the experiment and the experimental diets were fed until they reached 103.2 kg liveweight. Feed intake and liveweight gain were recorded regularly to develop quadratic functions between (i) daily weight gain and lysine level; and (ii) feed:gain ratio and lysine level. The authors developed separate quadratic response equations for male and female pigs for the five liveweight categories: 20-35, 35-50, 50-65, 65-80, and 80-95 kg. To demonstrate the application of differential calculus in determining optimum levels of lysine, we will make use of the quadratic equations for 50-65 kg female pigs:

$$y = -3250x^2 + 4077x - 304 \quad \text{(Daily weight gain)}$$
$$y = 4.93x^2 - 6.32x + 4.26 \quad \text{(Feed:gain ratio)}$$

where: $y =$ Daily weight gain (g) or Feed:gain ratio (g/g)
$x =$ Lysine level (g/MJ DE)

Optimum Lysine Level for Maximum Daily Weight Gain

Here, the aim is to find out the lysine level which will maximise the daily weight gain. We will make use of differential calculus to determine the optimum lysine level.

Step 1: Let us call the daily weight gain response function as Eqn (1)

$$y = -3250x^2 + 4077x - 304 \qquad \text{Eqn (1)}$$

Step 2: Find the first derivative of Eqn (1)

We will make use of the following rules to solve this question:

If $y = x^n$, then $y' = nx^{n-1}$
If $y = x$, then $y' = 1$
If $y =$ constant, then $y' = 0$

$$y = -3250x^2 + 4077x - 304$$
$$y' = -3250(2x^{2-1}) + 4077 \times 1 - 0$$
$$y' = -6500x + 4077$$

Step 3: Set $y' = 0$ and find the value of x

$$y' = 0$$
$$-6500x + 4077 = 0$$
$$6500x = 4077$$
$$x = \frac{4077}{6500} = 0.63$$

Step 4: Find the second derivative of Eqn (1)

The second derivative can be found by differentiating the first derivative (y').

$$y' = -6500x + 4077$$

We will make use of the following rules to solve this question:

If $y = x$, then $y' = 1$

If $y = \text{constant}$, then $y' = 0$

$$y' = -6500x + 4077$$
$$y'' = -6500 \times 1 + 0 = -6500$$

Step 5: Perform the second derivative test.

As y'' is negative, the value of $x = 0.63$ will give us the maximum value of y.

Step 6: Find the maximum value of y.

$$y = -3250 \times (0.63)^2 + 4077 \times 0.63 - 304$$
$$y = 975 \text{ g}$$

Answer: We can achieve maximum daily weight gain of 975 g by using lysine level of 0.63 g/MJ DE (Figure 4)

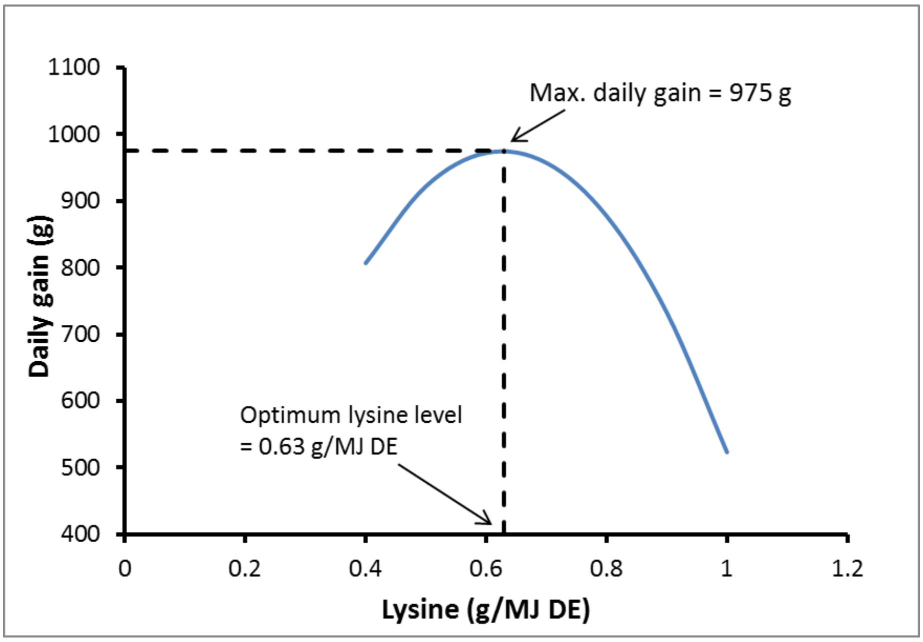

Figure 4: Quadratic response curve for the daily weight gain of female pigs in 50-65 kg liveweight range.

Optimum Lysine Level for Minimum Feed:Gain Ratio

Here, the aim is to find out the lysine level which will minimise the feed:gain ratio. We will make use of differential calculus to determine the optimum lysine level.

Step 1: Let us call the feed:gain response function as Eqn (1)

$$y = 4.93x^2 - 6.32x + 4.26 \qquad \text{Eqn (1)}$$

Step 2: Find the first derivative of Eqn (1)

We will make use of the following rules to solve this question:

If $y = x^n$, then $y' = nx^{n-1}$
If $y = x$, then $y' = 1$
If $y = \text{constant}$, then $y' = 0$

$$y = 4.93x^2 - 6.32x + 4.26$$
$$y' = 4.93(2x^{2-1}) - 6.32 \times 1 + 0$$
$$y' = 9.86x - 6.32$$

Step 3: Set $y' = 0$ and find the value of x

$$y' = 0$$
$$9.86x - 6.32 = 0$$
$$9.68x = 6.32$$
$$x = \frac{6.32}{9.86} = 0.64$$

Step 4: Find the second derivative of Eqn (1)

The second derivative can be found by differentiating the first derivative (y').

$$y' = 9.86x - 6.32$$

We will make use of the following rules:

If $y = x$, then $y' = 1$
If $y = \text{constant}$, then $y' = 0$

$$y' = 9.86x - 6.32$$
$$y'' = 9.86 \times 1 - 0 = 9.86$$

Step 5: Perform the second derivative test.

As y'' is positive, the value of $x = 0.64$ will give us the minimum value of y.

Step 6: Find the minimum value of y.

$$y = 4.93 \times (0.64)^2 - 6.32 \times 0.64 + 4.26$$
$$y = 2.23$$

Answer: We can achieve minimum feed:gain ratio of 2.23 by using lysine level of 0.64 g/MJ DE (Figure 5).

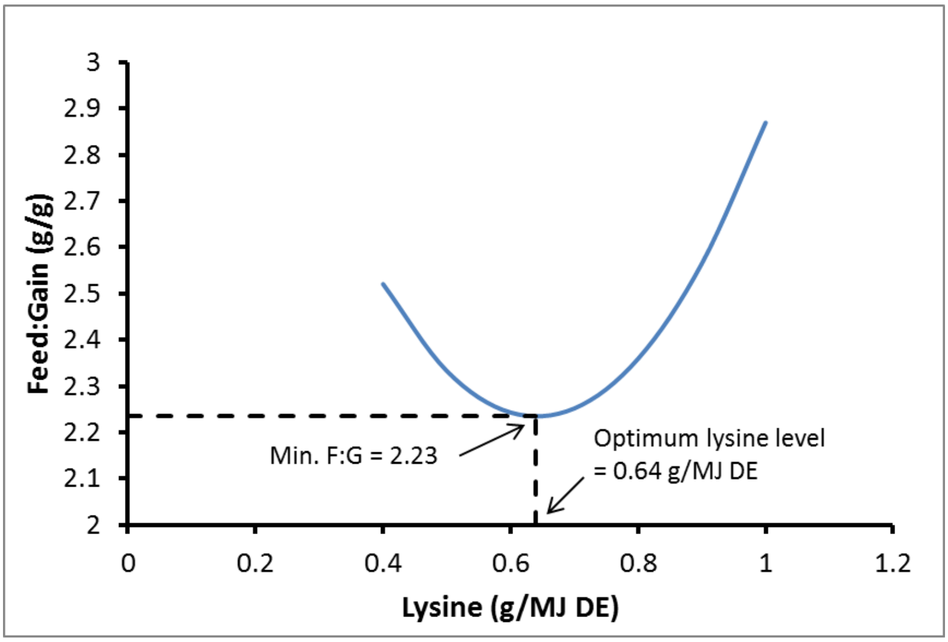

Figure 5: Quadratic response curve for the feed:gain ratio of female pigs in 50-65 kg liveweight range.

Summary

The lysine level for obtaining maximum daily weight gain is 0.63 g/MJ DE. Minimum feed:gain ratio can be achieved at 0.64 g/MJ DE. While these two values are close to each other for female pigs in 50-65 kg liveweight range, that may not be the case for other liveweight categories. If these lysine levels differ greatly from each other, then the choice of **optimum** lysine level is a compromise between maximum daily weight gain of pigs and minimum feed:gain ratio. It is normally recommended to take an average value of lysine level for the purpose of preparing pigs' rations.

Case Study 4: Bioavailability of drugs

LeTraon, G., Burgaud, S. and Horspool, L.J.I. (2008). Pharmacokinetics of cimetidine in dogs after oral administration of cimetidine tablets. *Journal of Veterinary Pharmacology Therapeutics*, 32:213-218.

Cimetidine is recommended to reduce vomiting in dogs with chronic gastritis. This study was conducted on eight dogs that were given cimetidine intravenously as well as oral tablets on separate occasions. Average dose rate was 5 mg/kg of bodyweight when cimetidine was administered intravenously whereas it was 5.3 mg/kg of bodyweight when administered orally. Blood samples were collected at 0, 5, 15 and 30 min and 1, 1.5, 2, 4, 6, 8, 10 and 12 hours after the intravenous injection and at 0, 15 and 30 min and 1, 1.5, 2, 3, 4, 6, 8, 10 and 12 hours after taking oral tablets.

The authors did not develop any relationships between plasma cimetidine concentration and time but presented their results graphically in their paper. Thus, we read the data from the graphs to develop the following relationships between plasma cimetidine concentration and time:

$$y = 3.7e^{-4.8x} + 2.8e^{-0.5x} \qquad \text{Eqn 1 (Intravenous)}$$

$$y = 1.82x - 0.80x^2 + 0.12x^3 - 0.0061x^4 \qquad \text{Eqn 2 (Oral)}$$

where: $y =$ Plasma cimetidine concentraion (μg/mL)
$x =$ Time (hours)

We will demonstrate the application of integral calculus in determining bioavailability of cimetidine following oral administration of cimetidine tablets. The plasma cimetidine concentration curves based on Eqn (1) and Eqn (2) are shown in Figure 6. Although blood samples were collected until 12 hours after administration of cimetidine, its concentration in plasma approached zero at 8 hours for both cases, so we will restrict our calculations for time between 0 and 8 hours. Bioavailability (F) is calculated using the following formula:

$$F = \frac{\text{AUC}_{niv}}{\text{AUC}_{iv}} \times \frac{\text{Dose}_{iv}}{\text{Dose}_{niv}}$$

Where:

AUC_{iv} = Area under the curve for intravenous route

AUC_{niv} = Area under the curve for non-intravenous route

Dose_{iv} = Amount of drug administered through intravenous route

Dose_{niv} = Amount of drug administered through non-intravenous route

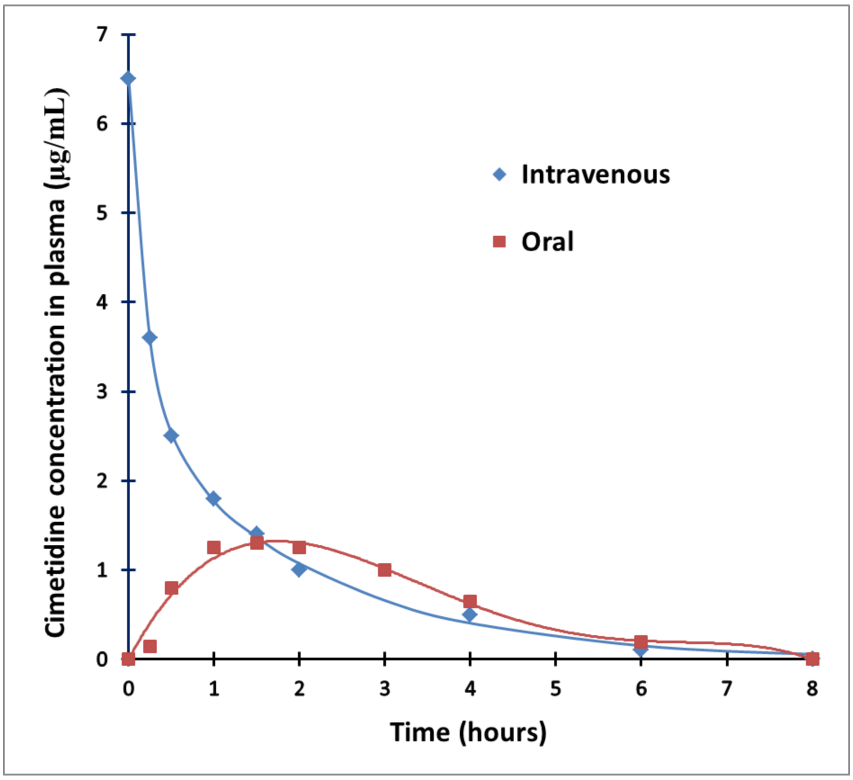

Figure 6: Plasma cimetidine concentration following intravenous and oral administration to eight dogs.

Step 1: Find the area under the curve (AUC_{iv}) for the intravenous route.

$$\int_0^8 (3.7e^{-4.8x} + 2.8e^{-0.5x})\,dx$$

$$= \left[-\frac{3.7e^{-4.8x}}{4.8} - \frac{2.8e^{-0.5x}}{0.5} \right]_0^8$$

$$= \left[-0.8e^{-4.8x} - 5.6e^{-0.5x} \right]_0^8$$

$$= \left[-0.8e^{-4.8(8)} - 5.6e^{-0.5(8)} \right] - \left[-0.8e^{-4.8(0)} - 5.6e^{-0.5(0)} \right]$$

$$= \left[-0.8e^{-38.4} - 5.6e^{-4} \right] - \left[-0.8e^{0} - 5.6e^{0} \right]$$

$$= \left[-1.7\times10^{-17} - 0.1 \right] - \left[-0.8 - 5.6 \right]$$

$$= [-0.1] - [-6.4] = 6.3$$

Answer: Area under the curve for intravenous route is 6.3 µg h/mL

Step 2: Find the area under the curve (AUC_{niv}) for the oral route.

$$\int_0^8 (1.82x - 0.80x^2 + 0.12x^3 - 0.0061x^4)\,dx$$

$$= \left[\frac{1.82x^2}{2} - \frac{0.80x^3}{3} + \frac{0.12x^4}{4} - \frac{0.0061x^5}{5}\right]_0^8$$
$$= \left[\frac{1.82\times(8)^2}{2} - \frac{0.80\times(8)^3}{3} + \frac{0.12\times(8)^4}{4} - \frac{0.0061\times(8)^5}{5}\right] - [0]$$
$$= 58.2 - 136.5 + 122.9 - 40.0$$
$$= 4.6$$

Answer: Area under the curve for oral route is 4.6 µg h/mL

Step 3: Find the Bioavailability (F) of cimetidine tablets.

$$F = \frac{\text{AUC}_{niv}}{\text{AUC}_{iv}} \times \frac{\text{Dose}_{iv}}{\text{Dose}_{niv}}$$
$$F = \frac{4.6}{6.3} \times \frac{5.0}{5.3} = 0.69 = 69\%$$

Case Study 5: Assessment of plant disease severity

Meena, P.D., Chattopadhyay, C., Meena, S.S. and Kumar, A. (2011). Area under disease progress curve and apparent infection rate of Alternaria blight disease of Indian mustard (*Brassica juncea*) at different plant age. *Archives of Phytopathology and Plant Protection*, 44(7):684-693.

Indian mustard is one of the major oilseed crops in the world. However, it is susceptible to Alternaria blight disease which can cause up to 47 per cent yield losses. Alternaria blight disease is caused by a pathogen known as *Alternaria brassicae*. Symptoms of the disease include formation of black spots on leaves and stems. Alternaria blight reduces the photosynthetic area and also affects the normal seed development, seed weight, seed colour, and oil content in the seed. The pathogen is greatly influenced by weather during the growing season and thus the planting date has a major effect on the incidence of disease.

This study was conducted to evaluate the effect of planting date on Alternaria blight disease progress curves of two cultivars (Varuna and Rohini) of Indian mustard crop. Both cultivars were planted at 10 different dates at weekly intervals (01, 08, 15, 22, 29 Oct, 05, 12, 19, 26 Nov and 03 Dec). Disease severity data were collected twice a week from the initial date of appearance until harvest. The authors did not develop any relationships between disease severity and days from disease appearance but presented their results in a tabular form in their paper. Thus, we used the raw data collected from the field experiment to develop relationships between disease severity and days from disease appearance for two different planting dates, 1 Oct (early planting) and 19 Nov (late planting), for the Varuna cultivar.

$$y = -0.00026x^3 + 0.02151x^2 + 0.18571x + 0.2 \qquad \text{(Early planting)}$$
$$y = 0.0032x^2 - 0.0413x \qquad \text{(Late planting)}$$

where: $y = \text{Disease severity (\%)}$
$x = \text{Number of days from disease appearance}$

The disease progress curves for the early planting and late planting are shown in Figure 7. The data are shown from the first day of disease appearance (x = 0) until harvest (x = 55). Thus, we will base our integral calculations for days between 0 and 55.

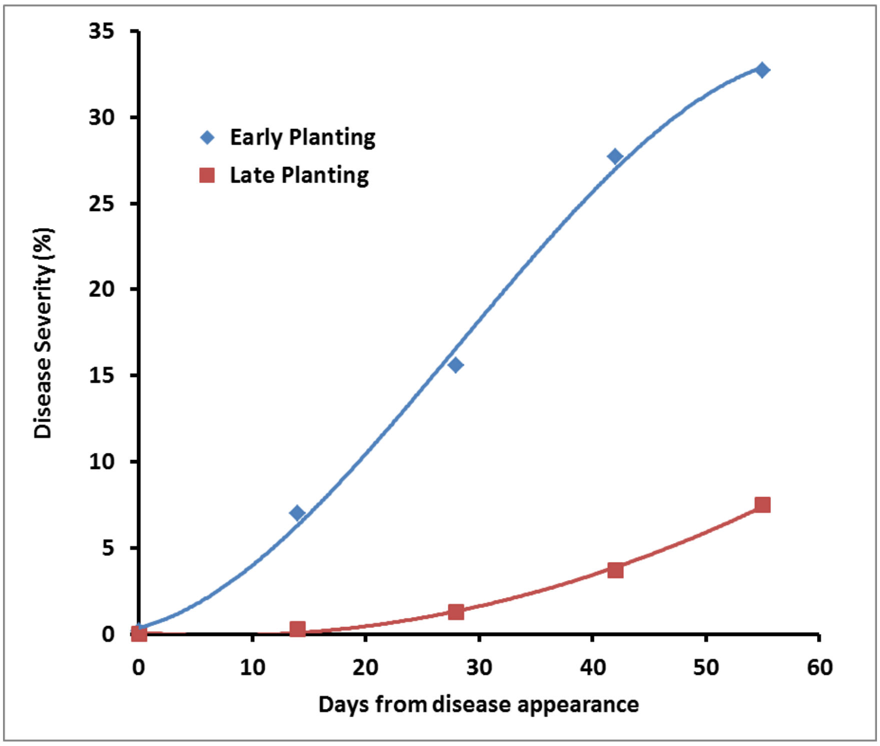

Figure 7: Severity of Alternaria blight on Indian mustard at different numbers of days from appearance of the disease.

Area under the disease progress curve (*AUDPC*) for early planting

Step 1

The area under the disease progress curve (*AUDPC*) for days between 0 and 55 is expressed as follows:

$$AUDPC = \int_0^{55} (-0.00026x^3 + 0.02151x^2 + 0.18571x + 0.2)dx$$

Step 2

Find the integral of the given function, $y = -0.00026x^3 + 0.02151x^2 + 0.18571x + 0.2$, enclose the result in square brackets and write the limits of integration on the right bracket.

We will make use of the following rules:

$$\int x^n dx = \frac{x^{n+1}}{n+1} + c$$

$$\int k dx = kx + c$$

As we are dealing with Definite Integral, we will ignore constant "c".

$$AUDPC = \left[\frac{-0.00026x^{3+1}}{3+1} + \frac{0.02151x^{2+1}}{2+1} + \frac{0.18571x^{1+1}}{1+1} + 0.2x\right]_0^{55}$$

$$= \left[\frac{-0.00026x^4}{4} + \frac{0.02151x^3}{3} + \frac{0.18571x^2}{2} + 0.2x\right]_0^{55}$$

Step 3

Evaluate the value of the integral at the upper limit of x =55

$$\frac{-0.00026x^4}{4} + \frac{0.02151x^3}{3} + \frac{0.18571x^2}{2} + 0.2x = \frac{-0.00026 \times 55^4}{4} + \frac{0.02151 \times 55^3}{3} + \frac{0.18571 \times 55^2}{2} + 0.2 \times 55$$

$$= -594.79 + 1192.91 + 280.89 + 11$$

$$= 890$$

Step 4

Evaluate the value of the integral at the lower limit of x = 0

$$\frac{-0.00026x^4}{4} + \frac{0.02151x^3}{3} + \frac{0.18571x^2}{2} + 0.2x = \frac{-0.00026 \times 0^4}{4} + \frac{0.02151 \times 0^3}{3} + \frac{0.18571 \times 0^2}{2} + 0.2 \times 0 = 0$$

Step 5

Find the difference between the values of integral at the upper limit and lower limit to find *AUDPC*.

AUDPC = 890

The area under the disease progress curve for early planting of Indian mustard is 890.

Area under the disease progress curve (AUDPC) for late planting

Step 1

The area under the disease progress curve (*AUDPC*) for days between 0 and 55 is expressed as follows:

$$AUDPC = \int_0^{55} (0.0032x^2 - 0.0413x)\, dx$$

Step 2

Find the integral of the given function, $y = 0.0032x^2 - 0.0413x$, enclose the result in square brackets and write the limits of integration on the right bracket.

We will make use of the following rules:

$$\int x^n dx = \frac{x^{n+1}}{n+1} + c$$

$$\int k\, dx = kx + c$$

As we are dealing with Definite Integral, we will ignore constant "c".

$$AUDPC = \left[\frac{0.0032x^3}{3} - \frac{0.0413x^2}{2} \right]_0^{55}$$

Step 3

Evaluate the value of the integral at the upper limit of x =55

$$\begin{aligned} \frac{0.0032x^3}{3} - \frac{0.0413x^2}{2} &= \frac{0.0032 \times 55^3}{3} - \frac{0.0413 \times 55^2}{2} \\ &= 177.47 - 62.47 \\ &= 115 \end{aligned}$$

Step 4

Evaluate the value of the integral at the lower limit of x = 0

$$\frac{0.0032x^3}{3}-\frac{0.0413x^2}{2}=\frac{0.0032\times 0^3}{3}-\frac{0.0413\times 0^2}{2}=0$$

Step 5

Find the difference between the values of integral at the upper limit and lower limit to find *AUDPC*.

AUDPC = 115

The area under the disease progress curve for late planting of Indian mustard is 115.

Summary

The area under the disease progress curve for late planting of Indian mustard is 115. Therefore, the severity of the disease at later planting date (115) is about 8 times lower than for the early planted crop (890). This indicates the potential for minimising the severity of the disease by delaying planting date.

Appendix C: Publication

Adaptive Tutorials: An E-learning Approach Fostering Student Engagement in Mathematics

Madan Gupta and Peter Adams
The University of Queensland, Australia

Abstract

Learning mathematics in distance mode offers unique challenges because it is abstract, sequential and has a large visual-spatial component with symbols and notations. A set of online adaptive tutorials were developed using Adaptive eLearning Technology to demonstrate the application of differential and integral calculus – two most challenging topics in mathematics which students often find difficult to grasp, resulting in poor performance and a higher failure rate. These adaptive tutorials combined the real world topic with the underlying mathematics, which motivated and engaged students to learn these topics. The system provides individualised guidance and instant feedback to students based on their level of understanding. The positive comments by students, such as 'I honestly found this the best learning tool of all' and 'I liked that the lesson was based on real applications, making it easy to engage with', sum up the many benefits offered by adaptive tutorials.

Note: This paper was presented at the 13th International Congress on Mathematical Education, Hamburg, Germany, 24-31 July 2016.

Appendix D: Evaluation of case studies

Professor Josua Pienaar
Deputy Dean (Learning & Teaching)
School of Engineering and Technology
Office 1.05
400 Kent Street
Sydney, NSW, 2000
AUSTRALIA
Tel +61 2 9324 5053

Email: j.pienaar@cqu.edu.au

Madan Gupta
University of Queensland
Gatton Campus

Dear Madan,

Re: Adaptive eTutorials

Thank you for the opportunity to review the case studies that you have created to teach differential and integral calculus with relation to the field of agriculture. These case studies provided students with authentic assessments in which to master and apply differential and integral calculus. I found the feedback given and the ability to reattempt very beneficial. Case studies of a similar nature to those that you have provided for your agriculture students would be most beneficial for our engineering and built environment students.

CQUniversity Australia would be pleased to partner the University of Queensland in future development of these resources and in an application for further grant funding.

Regards,

Prof. Josua Pienaar
Deputy Dean (Learning and Teaching)
School of Engineering and Technology